Seismic Attributes - from Interactive Interpretation to Machine Learning

Kurt J. Marfurt (The University of Oklahoma)

Geometric Attributes that Map Reflector Configuration

Shape Index and Curvedness

Geometric attributes that map reflector configuration

1. Dip magnitude and dip azimuth
2. Reflector convergence
3. Reflector nonparallelism
4. Curvature and aberrancy
5. Shape index and curvedness

The Shape Index and Curvedness

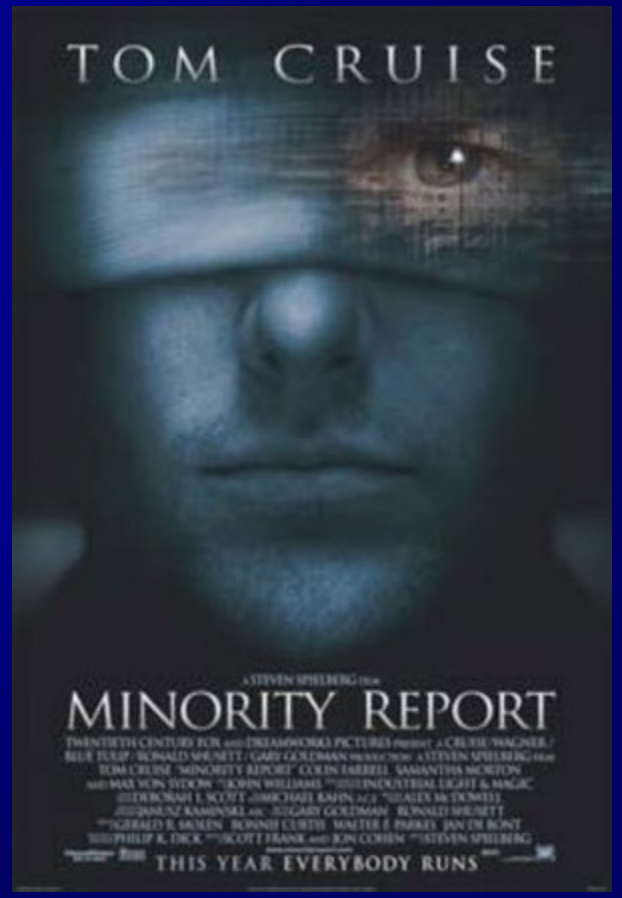
After this section you will be able to:

- Use the shape index and curvedness to delineate features that have dome, ridge, saddle, valley, bowl, and planar shapes
- In interactive interpretation, use the shape index modulated by curvedness to construct carbonate buildup and karst collapse geobodies
- In machine learning interpretation, use the shape components to help differentiate target features with a given shape from the general geologic background

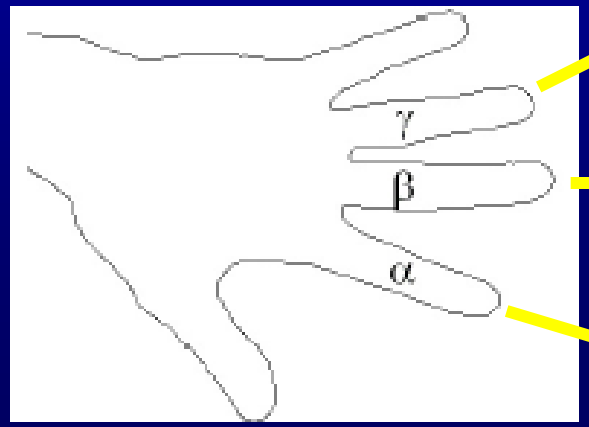
Shape index and biometric identification

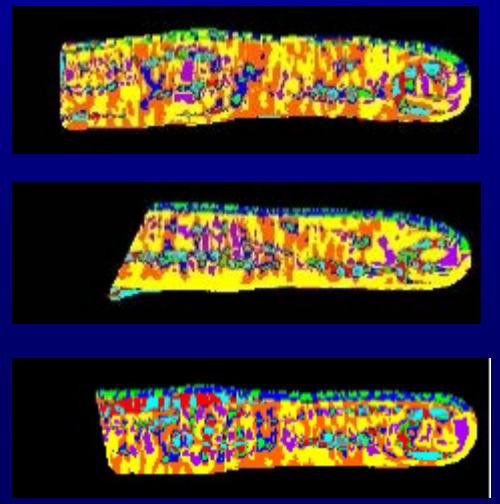
photographic image

distance scan

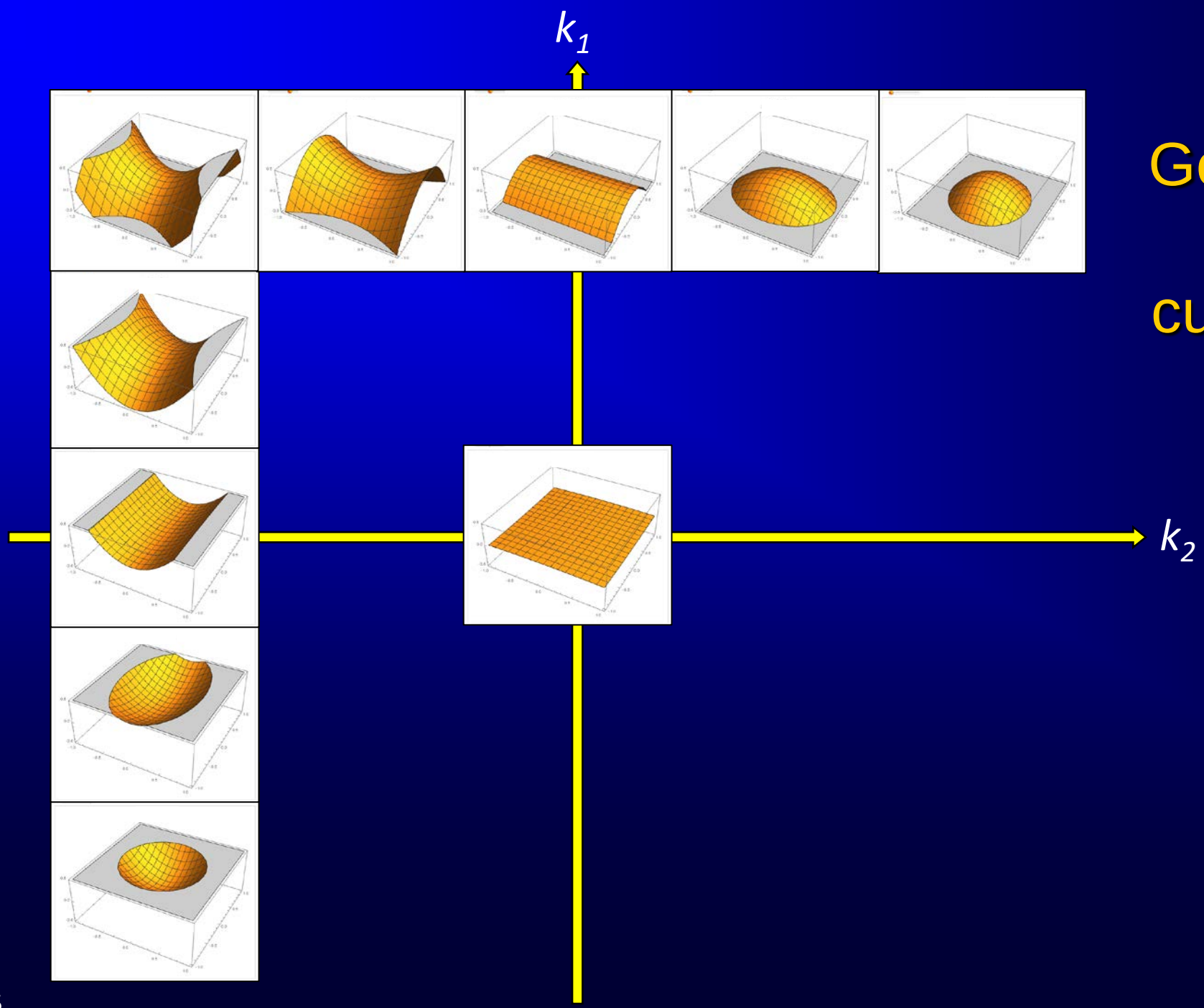


Shape indices



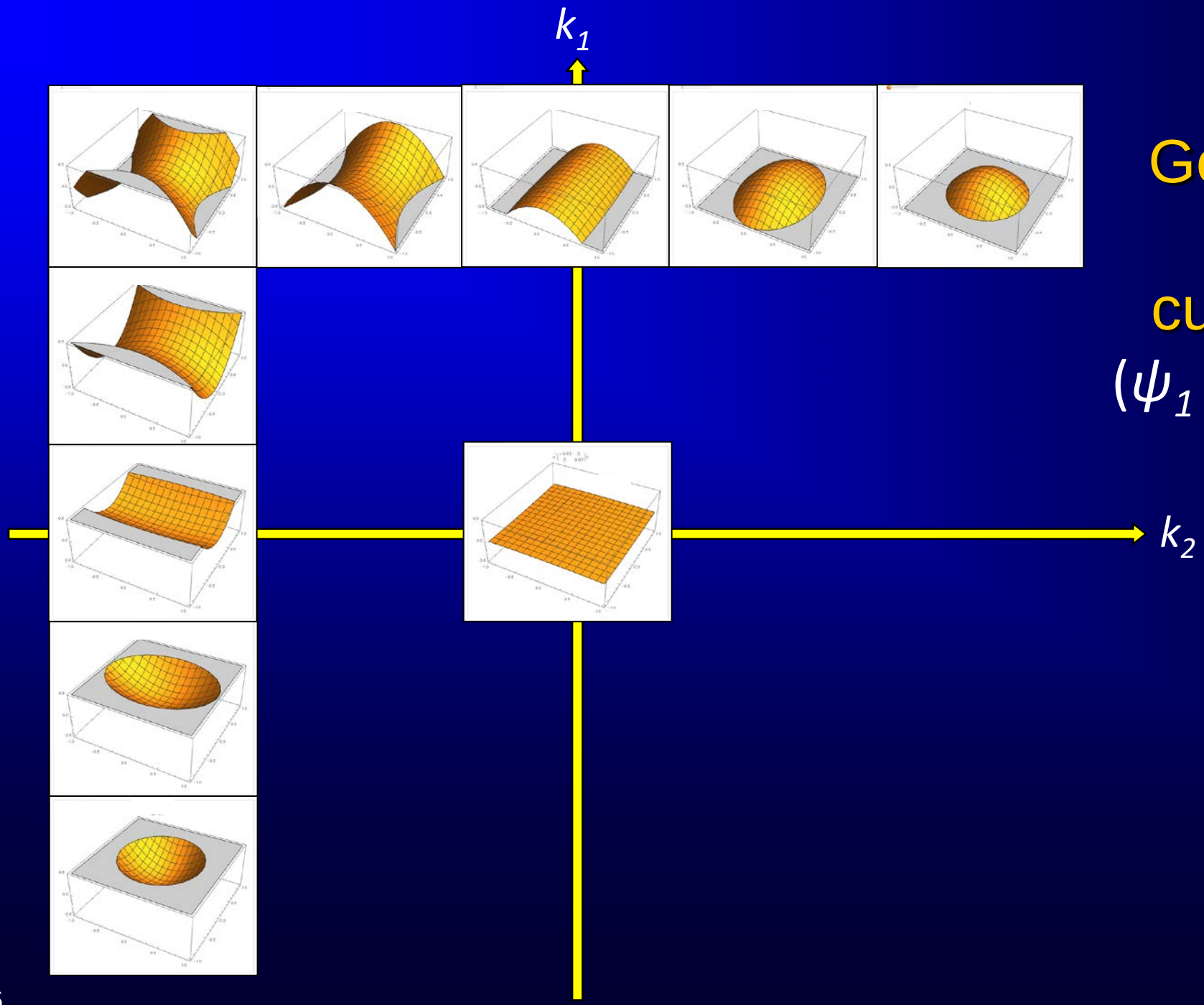


(Woodward and Flynn, 2004)



Geometry defined by the two principal curvatures, k_1 and k_2

(Marfurt, 2018)



Geometry defined by the two principal curvatures, k_1 and k_2
(ψ_1 and ψ_2 rotated by 90°)

(Marfurt, 2018)

The principal curvatures:

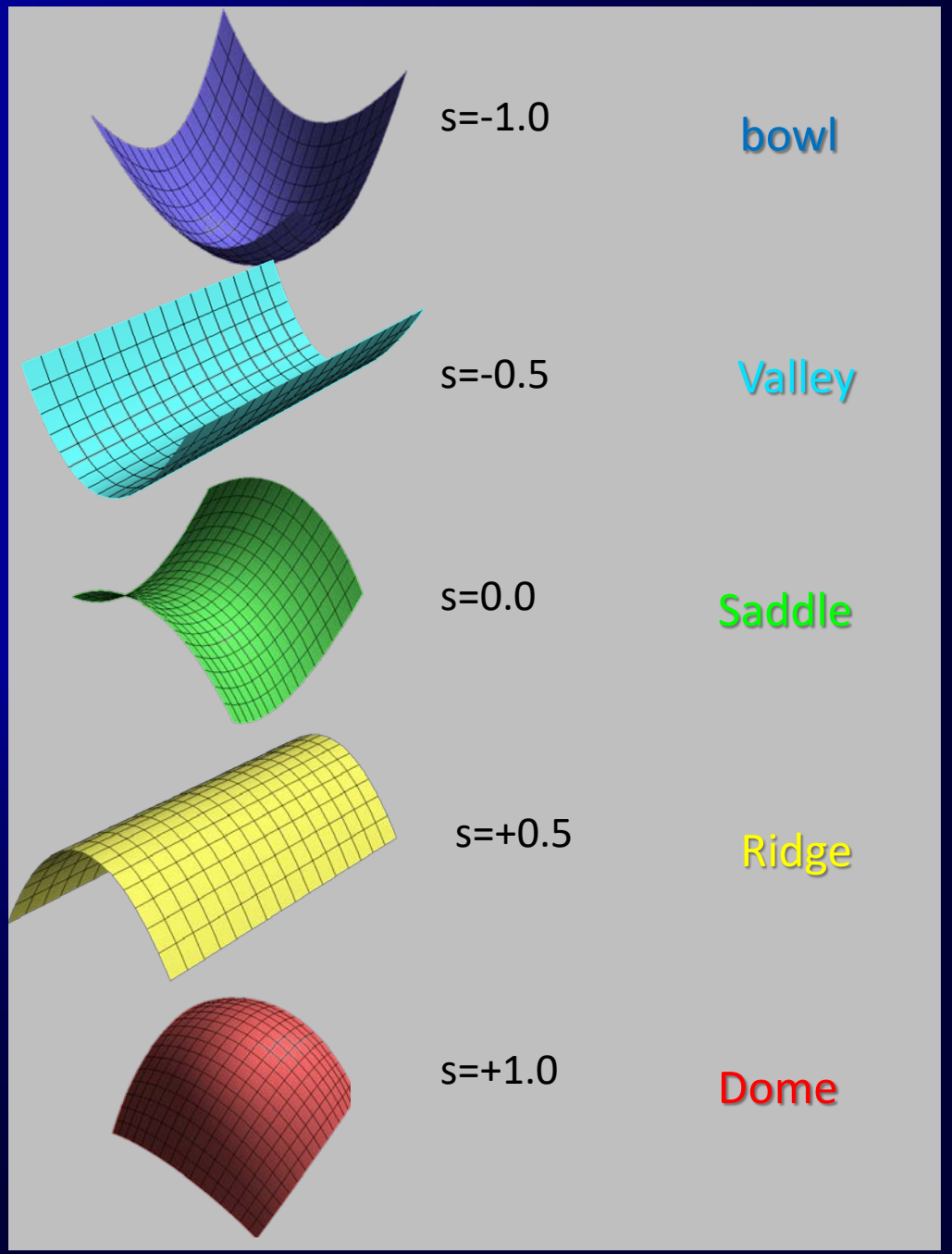
$$k_1 \geq k_2$$

The shape index, s:

$$s = -\frac{2}{\pi}\,\mathbf{ATAN}\left(\frac{k_2 + k_1}{k_2 - k_1}\right)$$

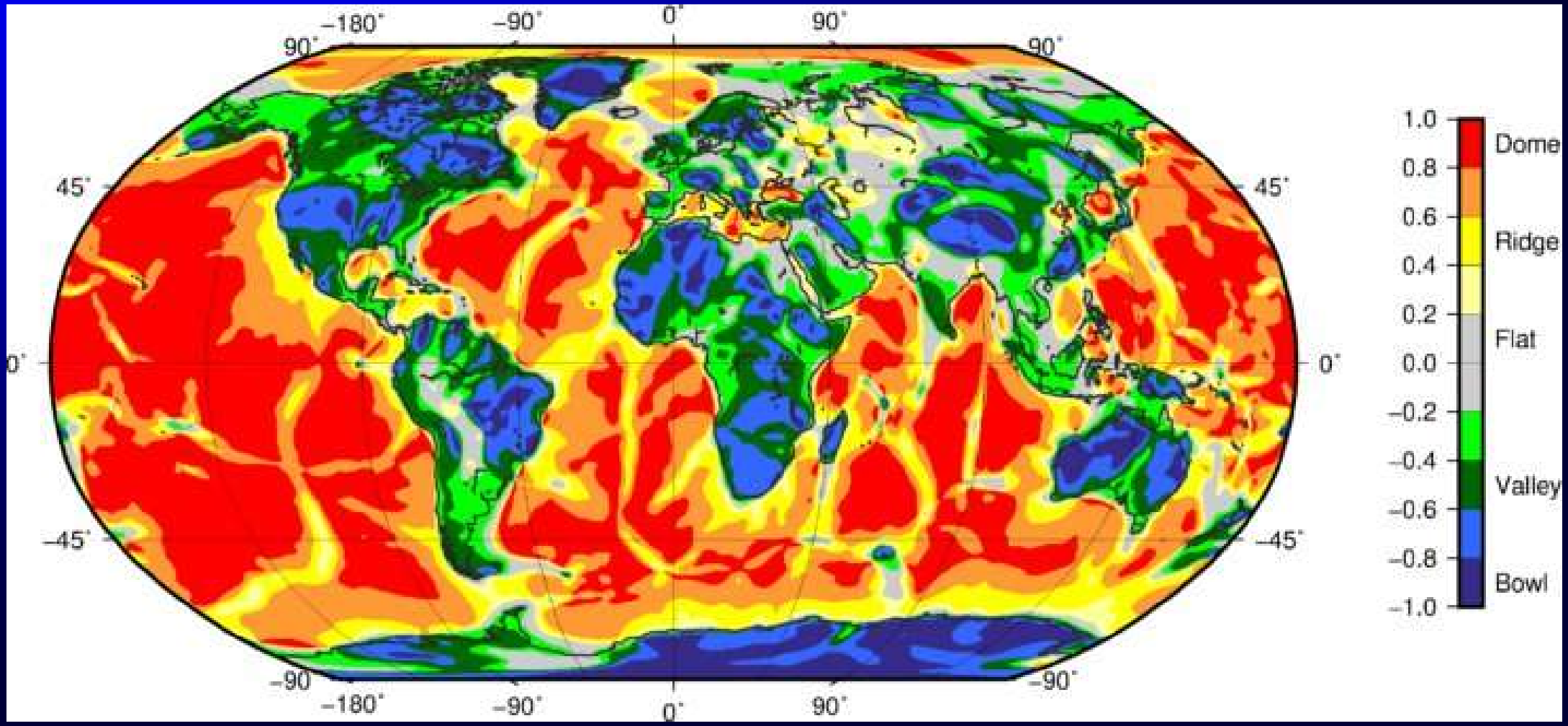
The curvedness, C:

$$C = \left(k_1^2 + k_2^2\right)^{1/2}$$

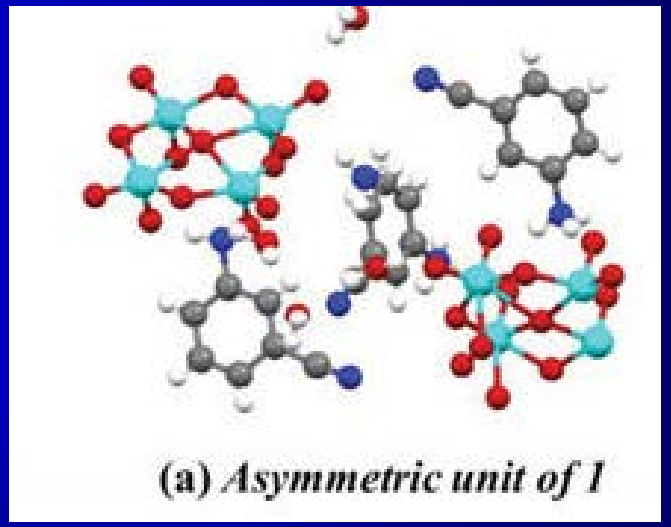


(Mai, 2010)

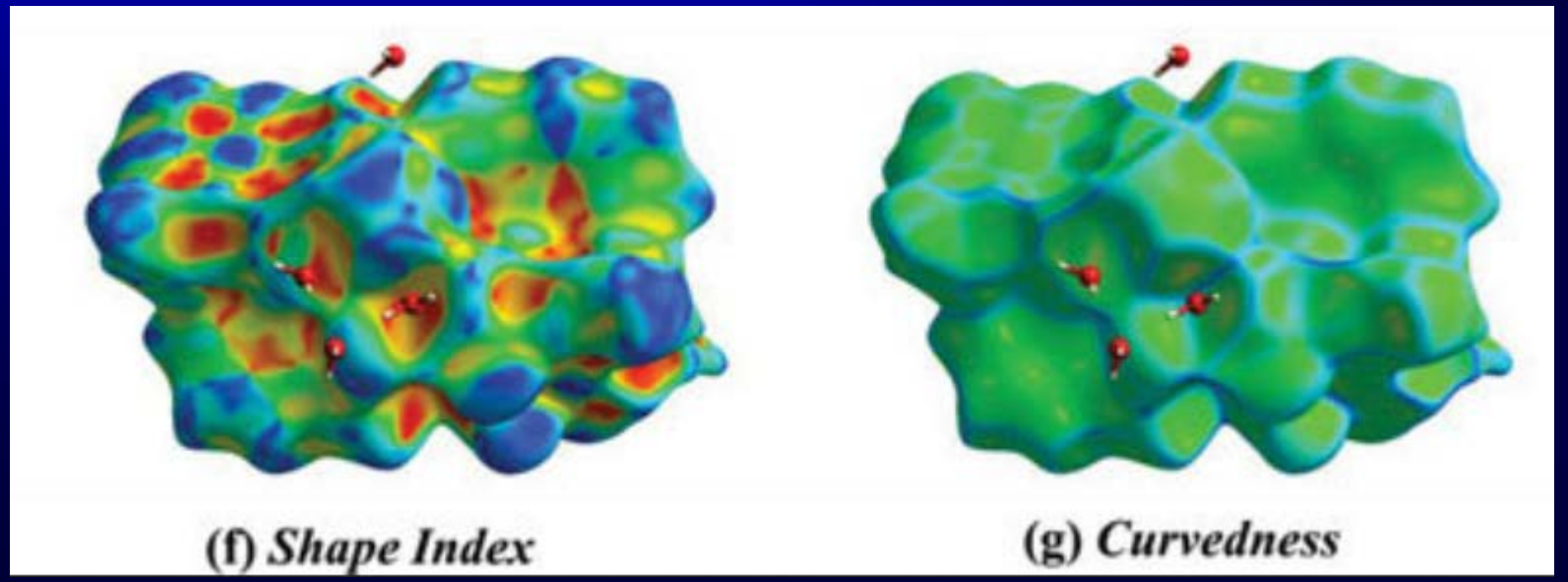
The shape of Earth's gravity field



Shape index and curvedness of molecules – used to map receptors



(a) *Asymmetric unit of 1*

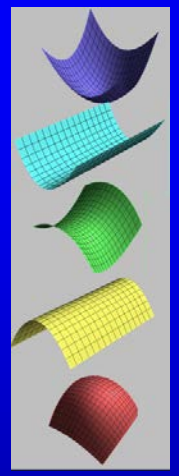


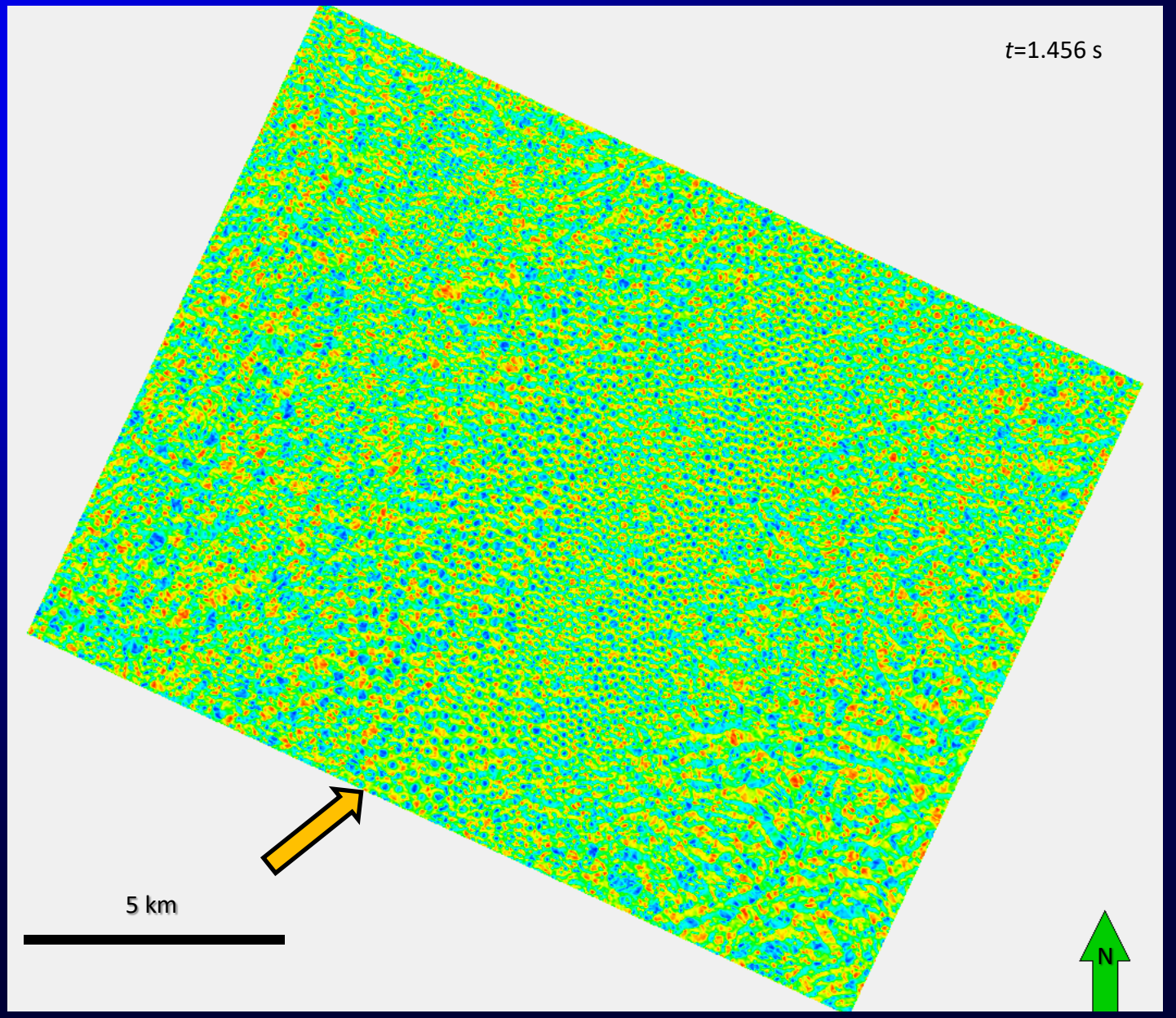
(f) *Shape Index* (g) *Curvedness*

Color bar inverted

(https://www.researchgate.net/profile/Amor_Haddad)

Shape index

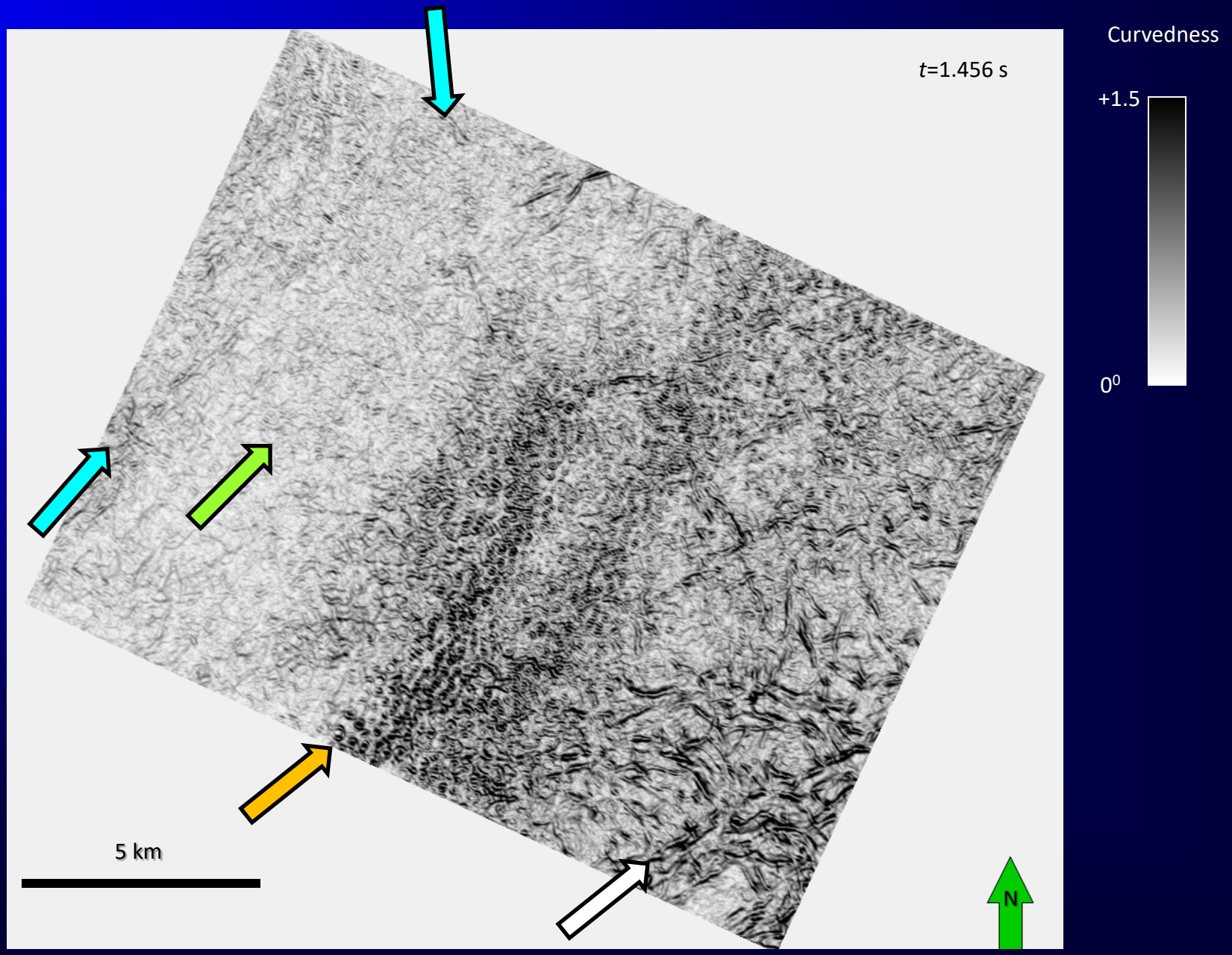




Great South Basin, NZ

(Marfurt, 2018)

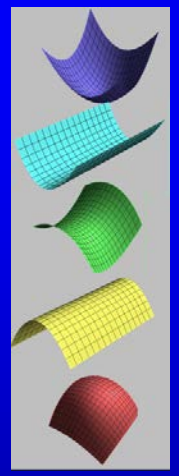
Curvedness

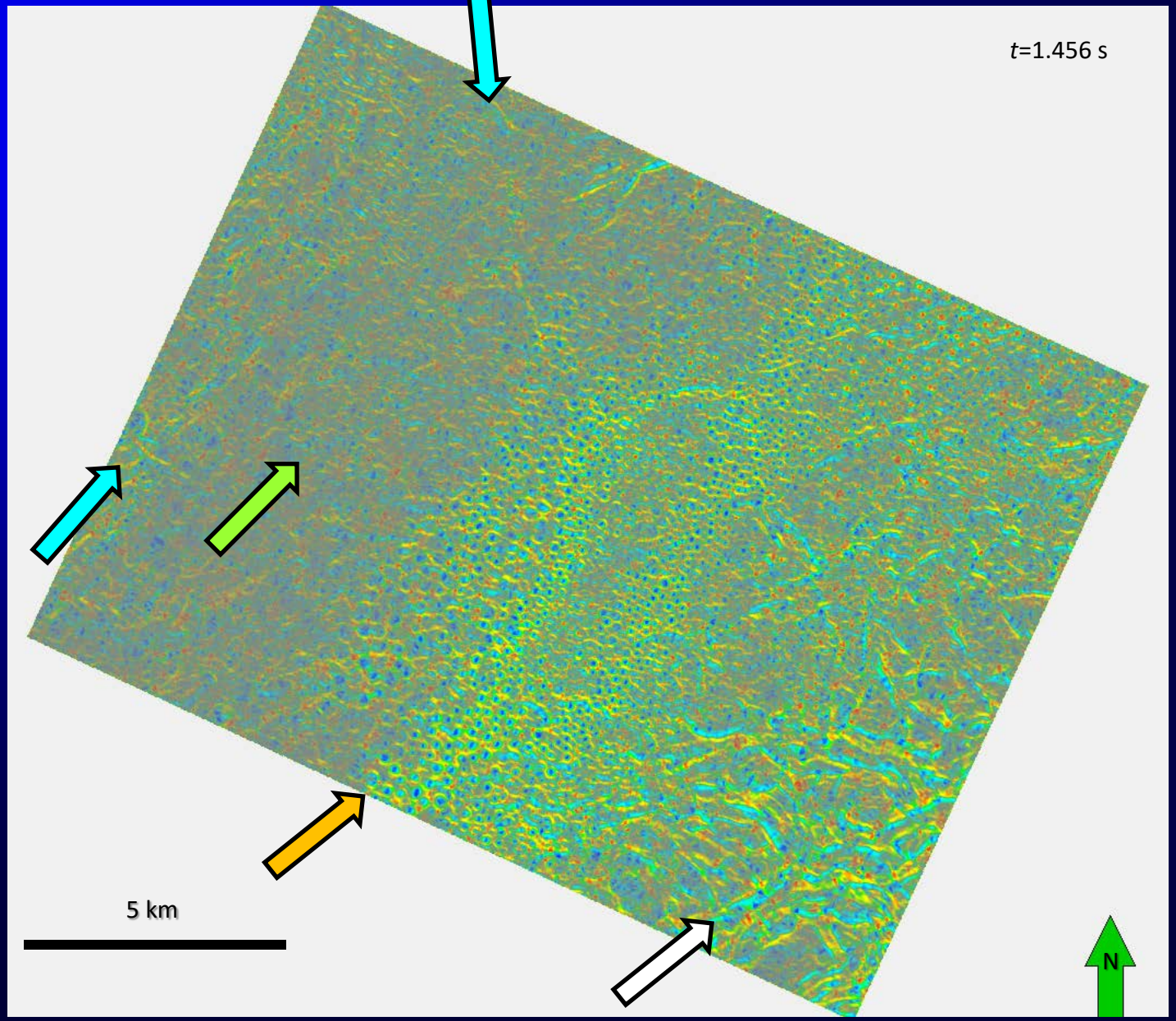


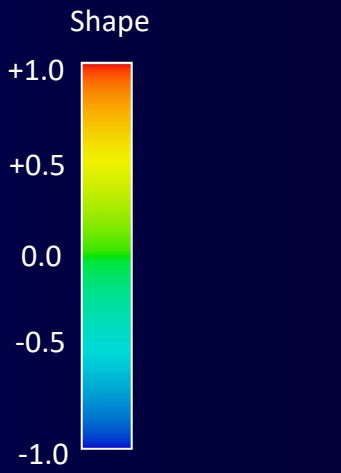
Great South Basin, NZ

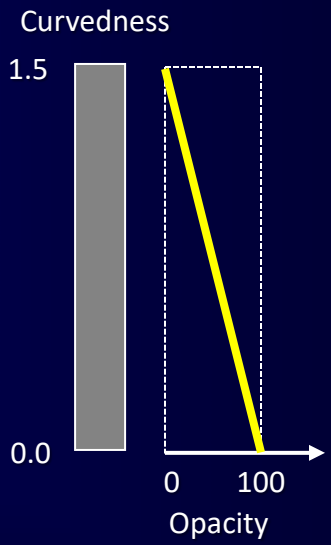
(Marfurt, 2018)

Shape index co-rendered with curvedness





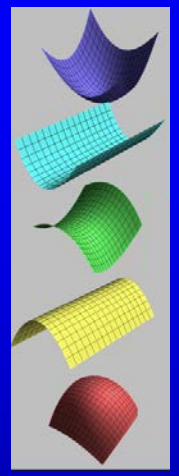


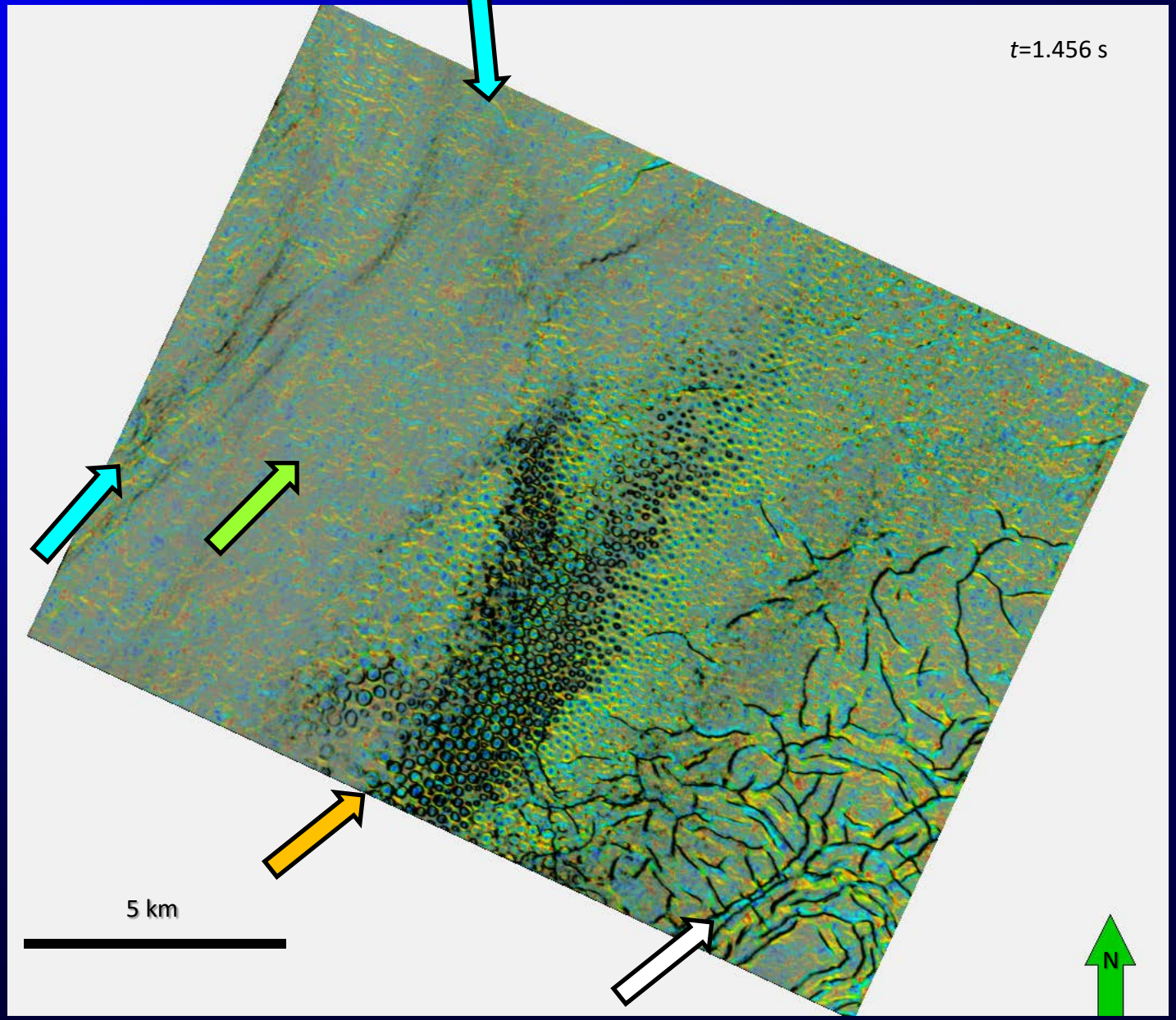


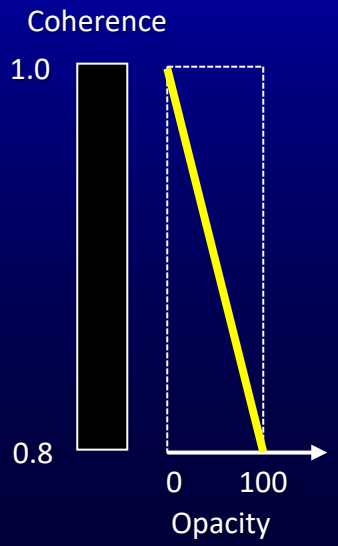
Great South Basin, NZ

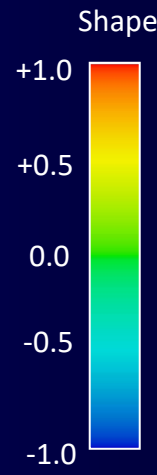
(Marfurt, 2018)

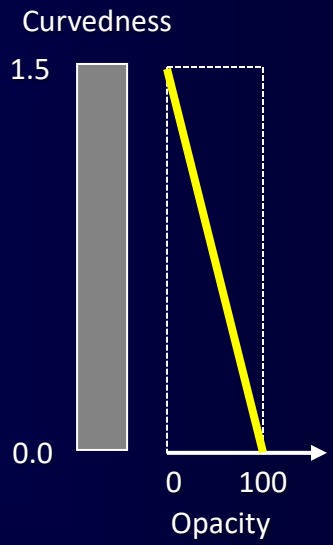
Shape index co-rendered with curvedness and coherence





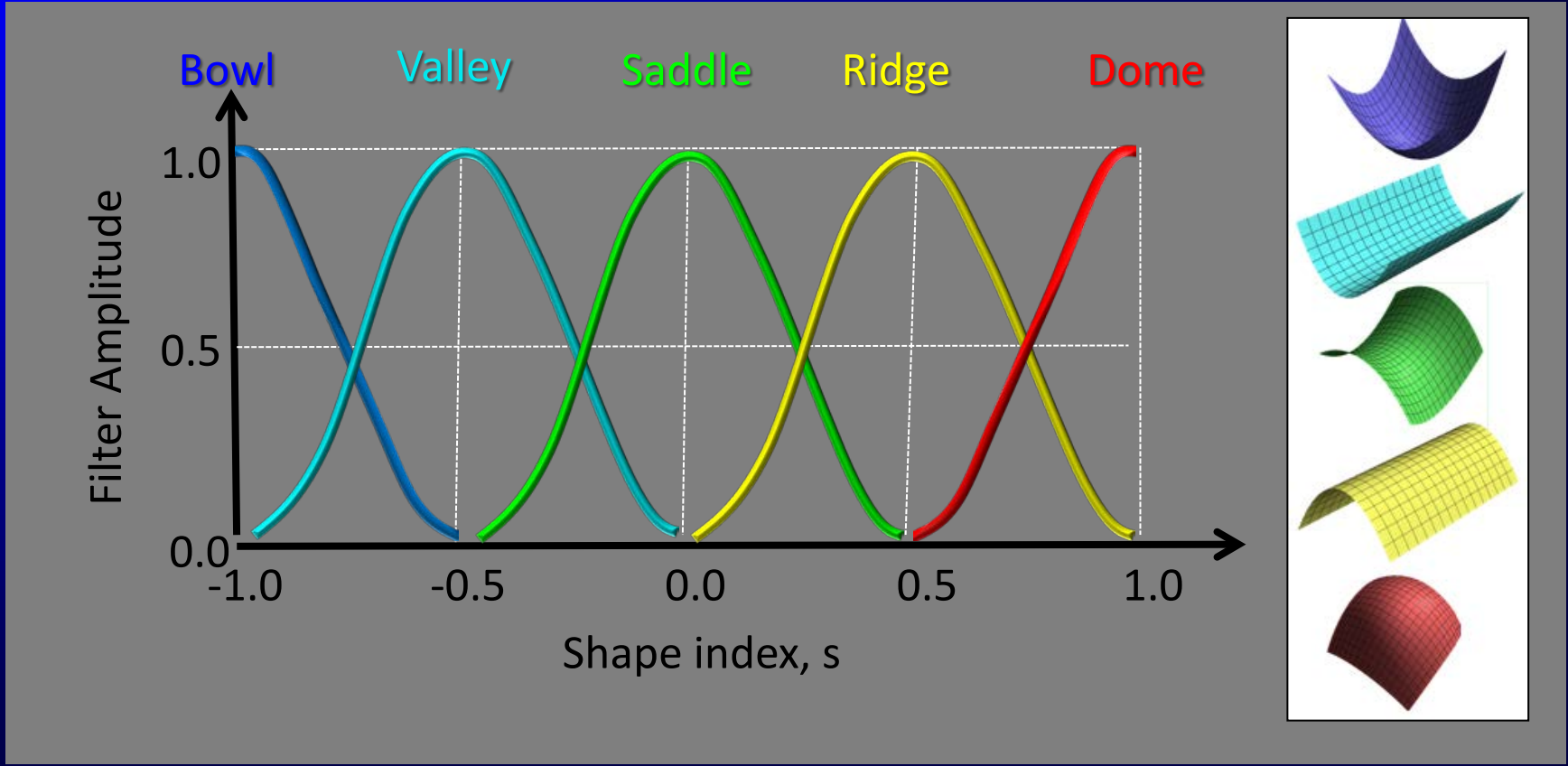






(Marfurt, 2018)

Filters to enhance structural shape components

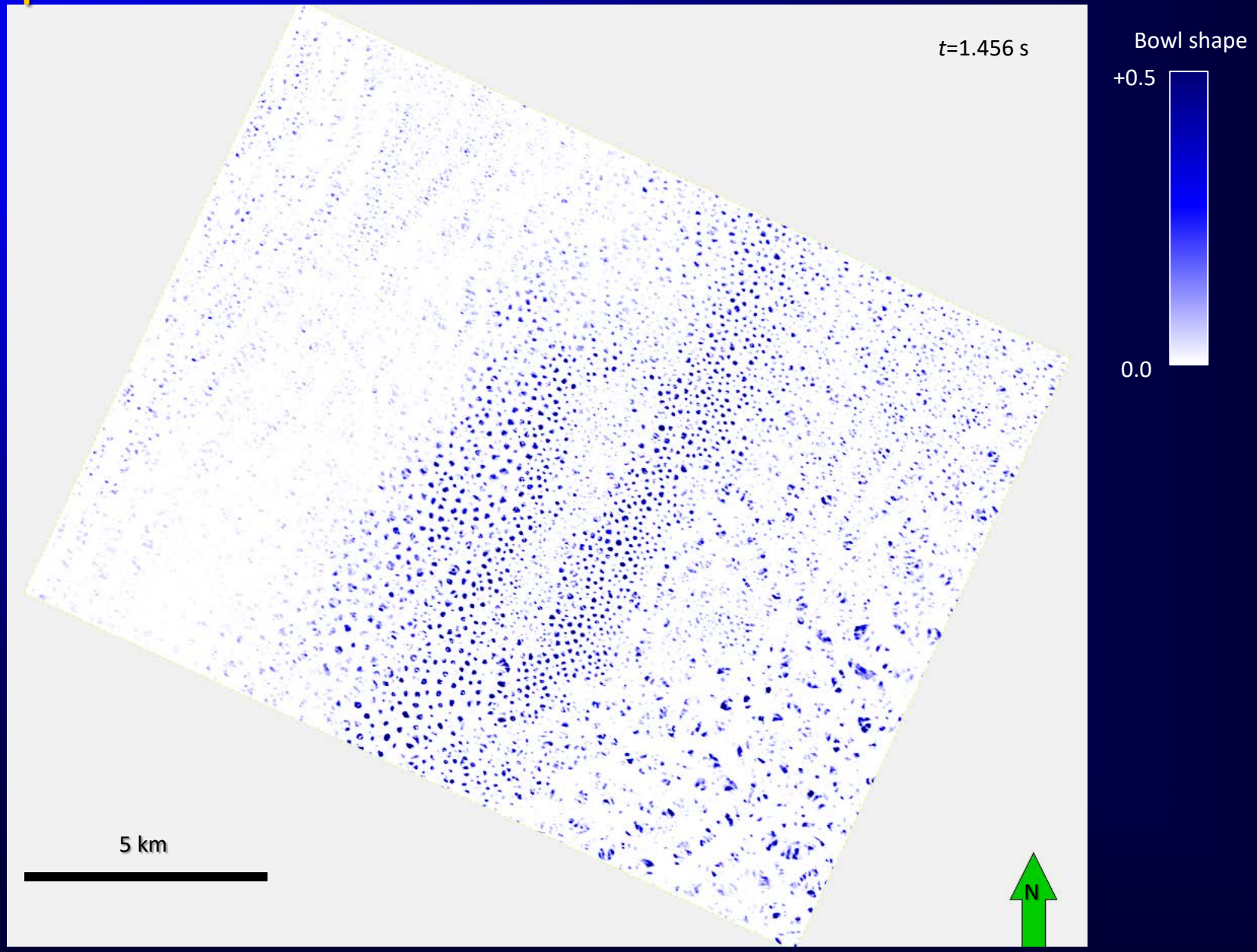


$$R_{\text{ridge}} = \begin{cases} k_{\text{curvedness}} COS\left[\pi(k_{\text{shape\_index}} - 0.5)\right] & \text{if} \quad 0.0 \le k_{\text{shape\_index}} \le 1.0 \\ 0 & \text{elsewhere} \end{cases}$$

Use an attribute calculator if necessary

(Marfurt, 2018)

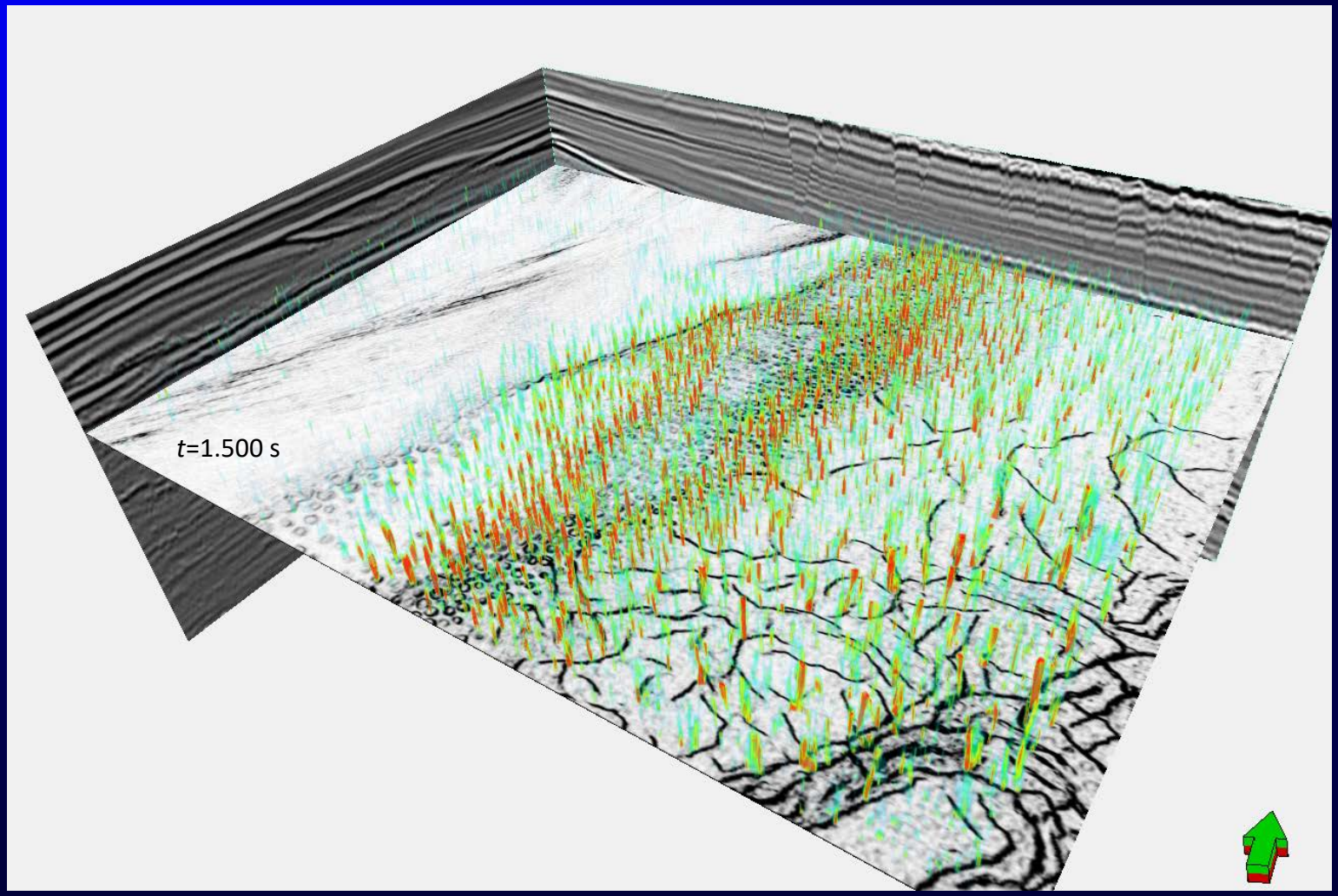
Bowl shape component

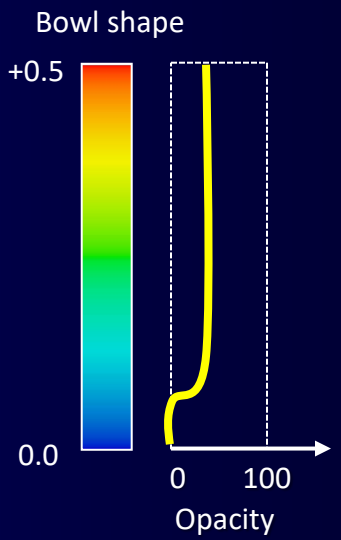


Great South Basin, NZ

(Marfurt, 2018)

Syneresis geobodies extracted as bowl shapes

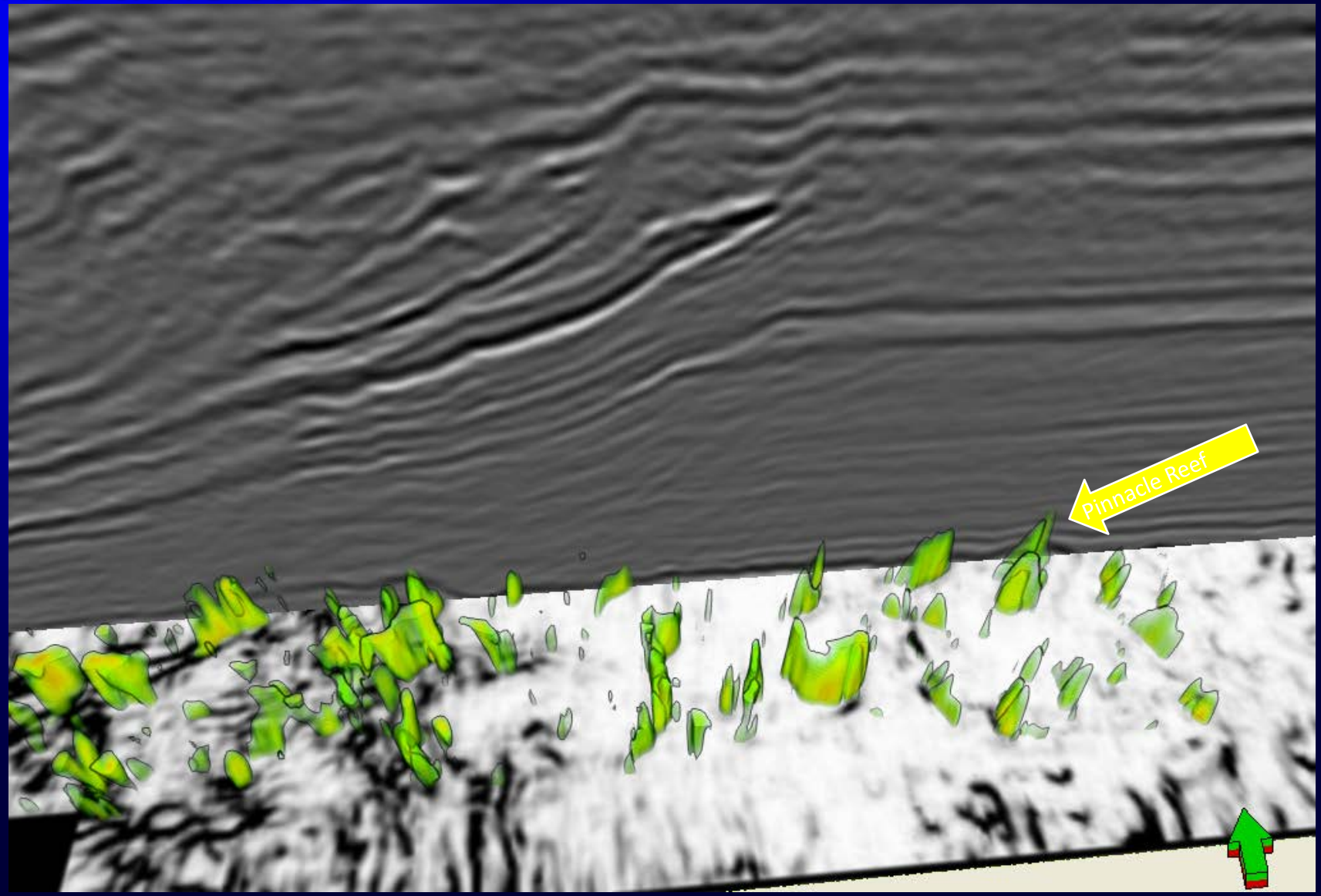




Great South Basin, NZ

(Marfurt, 2018)

Boxprobe rendering of ridge and dome shapes with a coherence time slice



Horseshoe Atoll,
west Texas, US

(Marfurt and Chopra, 2010)

Shape index and curvedness

In Summary:

- The shape index and curvedness form a pair, where the shape index defines the morphology and the curvedness the degree of deformation
- For planar events, the curvedness is zero and the value of the shape index is meaningless
- A simple filter applied to the shape index and curvedness provides a volume that measures the probability that any voxel has a given shape
- Shape components will be useful input to machine learning facies classification in identifying channels, carbonate reefs, and karst collapse